MEMO

Date:	December 4, 2015
Project No.	C150132.00
To:	Michael Glagola
From:	Kenneth Kinder
cc:	Michael Winters, John Klamut, Charlie Straley
Subject:	**Pond D Rapid Drawdown Analysis and Dewatering Volume Evaluation**

Mr. Glagola,

For the closure of Pond D at the Possum Point Power Station, the free water in the impoundment will be removed by pumping. It is anticipated that the water will be removed by pumping at a rate to lower the water level in the pond on the order of 1 to 2 feet per day. The lowering of the pond will create excess pore pressure developing within the interior slope of the pond embankment which will dissipate over time.

In order to evaluate the stability of the interior slope of the pond, stability analyses were performed to evaluate the embankment slope with existing groundwater levels, post-draining groundwater levels, and the condition of rapid drawdown with the ground water level on the ground surface, The attached calculations summarize the stability analyses with these conditions.

The "most-critical" scenario is the rapid drawdown condition, which considered the free water theoretically being instantaneously removed from the impoundment. This analysis resulted in a Factor of Safety of 1.3, which is greater that the desired Factor of Safety of 1.2 (Table 3-1, Corps of Engineers Slope Stability Engineering Manual, EM 1110-2-1902, 2003).

The anticipated drawdown rate of the water surface in Pond D will be controlled by the pumping rate and treatment capacity of the water treatment system. The anticipated drawdown rate of free water from Pond D is not expected to exceed 1 to 2 feet per day. The rapid drawdown condition had a factor of safety greater than the desired factor of safety. Therefore, a drawdown rate of 1 to 2 feet per day should not cause instability of the upstream face of the embankment slope.

GAI also calculated the volume of water contained in the ash to assist with estimating dewatering pumping rates. GAI estimated the range of water extraction volumes for Pond D to be approximately 50 million to 70 million gallons. The attached calculations summarize the dewatering water volume evaluation.

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RAPID DRAWDOWN STABILITY ANALYSES

OBJECTIVE:

Evaluate rapid drawdown rotational failure surfaces under static conditions for the proposed dewatering of Pond D at the Dominion Possum Point Power Station located in Prince William County, Virginia.

METHODOLOGY:

Stability will be evaluated under static conditions using two-dimensional limit equilibrium analysis with the design software Slope/W by GeoStudio 2007, version 7.23.

REFERENCES:

1. Stability Modeling with SLOPE/W 2007 Version. Program documentation. Vers. 7.23. GEO-SLOPE International Ltd.
2. Corps of Engineers (2003) "Appendix G - Procedures and Examples for Rapid Drawdown". Engineering Manual, EM 1110-2-1902. Department of the U.S Army Corps of Engineers.

BACKGROUND:

Dominion is proposing the closure of Pond D located at the Possum Point Power Station in Prince William County, Virginia. Pond D is located just north of the power station and will include an approximately 70 acre geosynthetic cap area.

Free water and ash dewatering water has been pumped from Pond ABC and Pond E and is being stored in Pond D. To facilitate the closure of Pond D, the free water will be removed from Pond D by pumping and treating prior to discharge. The anticipated drawdown rate of the water surface in Pond D will be controlled by the pumping rate and treatment capacity of the water treatment system. The anticipated drawdown rate is not expected to exceed 1-2 feet per day.

PURPOSE:

Dominion anticipates dewatering Pond D at a rate of up to 1-2 feet per day. During rapid drawdown, the stabilizing effect of the water on the upstream face is lost, but the pore water pressures within the embankment could remain high immediately after drawdown. As a result, the stability of the upstream face of the embankment can be reduced. The dissipation of the pore water pressures in the embankment is largely influenced by the permeability and the storage characteristics of the embankment materials. Highly permeable materials drain quickly during rapid drawdown, but low permeability materials take a long time to drain. Slope/W was used to analyze the rapid drawdown by using the effective stress approach. This procedure, in essence, means the change in pore-pressure is equal to the vertical change in water level, and that the total stress change is equal to the pore-pressure change so that the effective stress remains unchanged.

ANALYSIS:

Short-term static stability analyses were performed along the perimeter embankment of Pond D to evaluate the upstream face stability during a rapid drawdown. One cross-section was selected to represent the most critical slope condition and the location of this section is shown on the figure presented in Attachment 1. Additionally, detailed information regarding the cross section geometry of the section is included in the slope stability software output presented in Attachment 3 (undrained analyses) and Attachment 4 (drained analyses).

The soil parameters used in the slope stability analyses are summarized in Attachment 2. The material properties used to represent the in-place embankment soils, clay foundation and drainage blanket were obtained from slope stability analyses previously completed for Pond D as part of the Final Design Report completed by Virginia Power, Engineering and Construction, Civil Engineering department (originally submitted

October, 1986). The analysis was completed using both drained and undrained parameters for ash, embankment soils and the clay foundation.

As-built drawings and aerial mapping were utilized to model bottom of existing ash, top of existing ash soil surfaces. The initial piezometric surface used in the analyses is based on the depth of ponded water encountered in Boring B-4 during the subsurface investigation conducted in June, 2015. The final piezometric surface used in the analysis is based on a proposed dewatering elevation equal to approximately 10-ft below the elevation of the in-place ash material.

Slope/W uses the piezometric line during the analysis to compute pore-water pressure at the base of each slice. By removing the ponded water through adjusting the piezometric line, the hydrostatic force offered by the ponded water is removed, but the effective stress remains the same at the base of each slice. Therefore, to model the rapid drawdown conditions, the piezometric line representing ponded water is lowered and follows the upstream ground surface, but remains unchanged in the embankment.

This approach is based on the assumption that the soil has some finite hydraulic conductivity such that the change in pore-water pressure at the base of the slice is instantaneously equal to the change in ponded water pressure head above the slice. Considering that water is incompressible and that soils near the slope face likely have some finite conductivity, this is not an unrealistic assumption.

Upstream stability analyses were performed for the initial ground water conditions, for the rapid drawdown conditions and for the final groundwater conditions.

A review of the laboratory results for the materials, including the clay liner material, utilized in the construction of the embankment indicates that the average Liquid Limit is less than 38 percent. Based on the empirical correlation, the coefficient of consolidation is estimated to be greater than 2 ft^2/day. The degree of consolidation will reach nearly a fully drained condition (assuming a 1-foot drainage distance). The excess pore pressure will dissipate quickly enough to not impact the stability of the embankment.

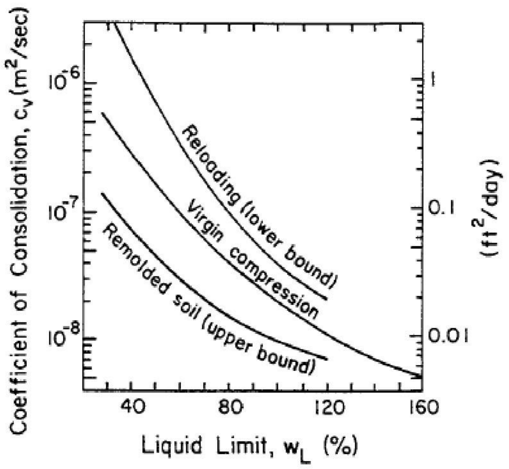


Figure 6-15. c_v versus w_L

Source: NAVFAC (21), p. 7.1-144.

Coefficient of Consolidation vs. Liquid Limit (NAVFAC, 1986)

SUMMARY:

Stability analyses performed for the upstream face during the proposed dewatering (initial, final and rapid drawdown scenarios) are summarized in Attachment 3 (undrained analyses) and Attachment 4 (drained analyses). Static conditions were evaluated using the Morgenstern-Price method which is an equilibrium method that considers both shear and normal inter-slice forces and satisfies both moment and force equilibrium. A large number of deep-seated failure surfaces were generated and the most critical failure surface for each analysis section was isolated to determine the minimum factor of safety.

The following table summarizes the results of static slope stability analyses considering both drained and undrained conditions for the upstream embankment face.

Analysis	Desired Factor of Safety(1)	Factor of Safety Undrained Conditions	Factor of Safety Drained Conditions
Initial GWT Steady State	1.5	2.24	1.69
Rapid Drawdown	1.2	1.88	(2)
Final GWT Steady State	1.5	2.22	1.73

Notes: (1) Desired Factors of Safety taken from Table 3-1 of the Corps of Engineers Slope Stability Engineering Manual, EM 110-2-1902, 2003 (Reference 2).

(2) Drained Conditions not present for Rapid Drawdown analysis. No value was computed.

As shown in the summary table above and in the SLOPE/W software output presented in Attachment 3 and Attachment 4, the resulting factors of safety calculated for static (drained and undrained) conditions are greater than 1.5 for the initial and final groundwater levels assuming steady state conditions. For the rapid drawdown case, the factors of safety were greater than 1.2 for both drained and undrained conditions. In addition, the excess pore pressure will dissipate with the embankment slope under a drawdown rate of 1 to 2 feet per day. Therefore, dewatering the pond at a rate of 1 to 2 feet per day is not anticipated to induce instability of the upstream embankment face.

ATTACHMENT 1

STABILITY ANALYSIS SECTION

MAPPING REFERENCE:

EXISTING TOPOGRAPHY PREPARED BY KEDDAL AERIAL MAPPING. PHOTOGRAPHY DATED 02-13-2015.
VA-N NAD83 (2011) NAVD88 (GEOID 12A) 1 FT. CONTOUR INTERVALS

SUPPLEMENTED BY GROUND SURVEY PERFORMED BY GAI CONSULTANTS, INC. AND FROM INFORMATION PROVIDED BY DOMINION.

ROW AND BOUNDARY SURVEY INFORMATION SHOWN BY GAI CONSULTANTS DATED, 7-27-2015

NO.:	DATE:	DWN:	CHK:	APV:	DESCRIPTION:

REVISION RECORD

DRAWING TITLE

STABILITY ANALYSIS SECTION - POND D CLOSURE

PROJECT

POSSUM POINT POWER STATION
COAL COMBUSTION RESIDUAL
SURFACE IMPOUNDMENT
CLOSURES
DUMFRIES, VA

CLIENT

VIRGINIA ELECTRIC AND
POWER COMPANY
GLEN ALLEN, VA

gai consultants

ISSUING OFFICE: Richmond | 4198 Cox Road, Suite 114, Glen Allen, VA 23060

DRAWN BY:	CHECKED BY:	APPROVED BY:
DOYLEMP	KINDEKW	KLAMUJR
DWG TYPE:	SCALE:	ISSUE DATE:
	AS SHOWN	12/3/2015

SHEET NO.: 1 OF 1

REVISION

GAI FILE NUMBER: POND D GEOTECH SECTION

ALT./CLIENT DRAWING NUMBER:

GAI DRAWING NUMBER: 1

PERMIT

ATTACHMENT 2

SUMMARY OF SLOPE STABILITY SOIL PARAMETERS

Summary Stability Analysis Design Parameters
Dominion - Possum Point Power Station
Pond D Closure

By: MEZ 07/08/15
Ck: KLS 7/9/15

Material	Total Unit Weight (pcf)	Undrained Shear Strength		Drained Shear Strength	
		Cohesion (psf)	Friction Angle (deg)	Cohesion (psf)	Friction Angle (deg)
Embankment Soil(1)	120.00	775.0	18.0	0.0	33.0
Clay Foundation(1)	125.00	750.0	15.0	200.0	25.0
Ash(2)	90.00	350.0	18.0	0.0	36.0
Final Cover Soil(3)	120.00	0.0	28.0	0.0	28.0
Drainage Blanket(1)	125.00	0.0	37.0	0.0	37.0

Notes:
(1) Unit weights and shear strengths estimated obtained from slope stability analysis performed as part of the Final Design Report completed for Pond D by Virginia Power, Enginering and Construction Civil Engineering Department, October 1986.
(2) Shear strength parameters estimated from consolidated undrained triaxial testing completed on representative samples taken from Pond D and in-situ CPT testing completed on Pond D in June, 2015.
(3) Parameters for final cover soil estiamted as lower range of typical values for sandy silt and clayey sands.

ATTACHMENT 3

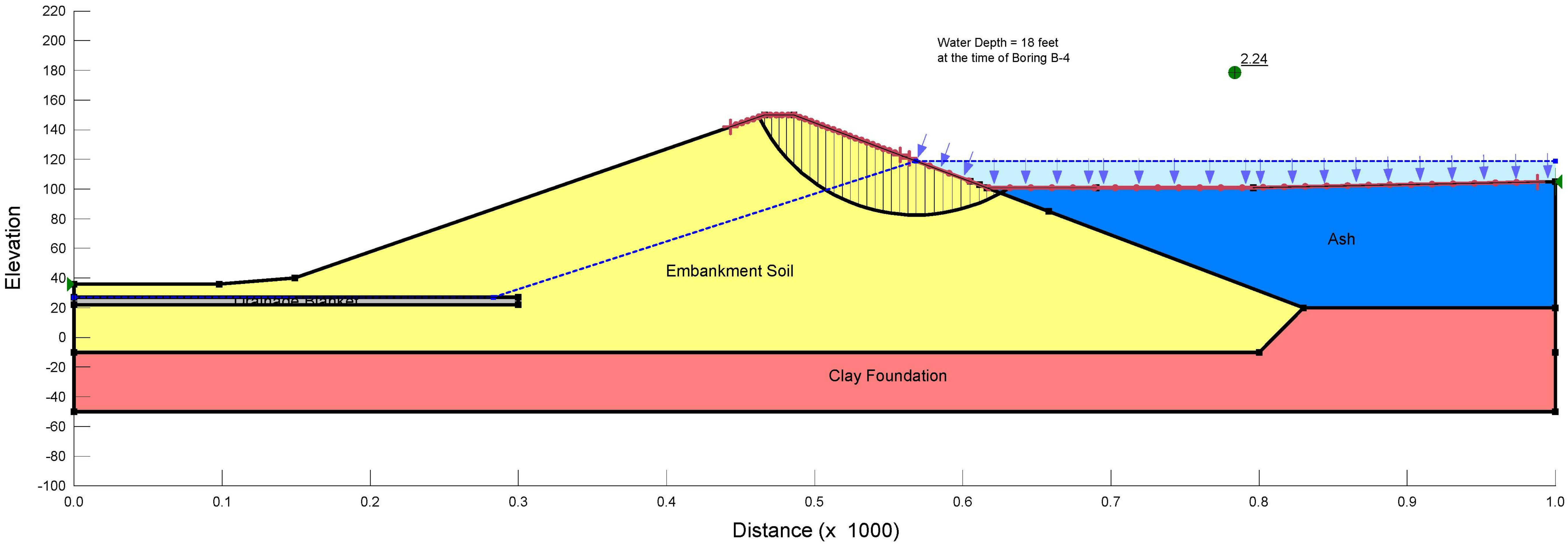
UNDRAINED SLOPE STABILITY ANALYSIS RESULTS

GAI Project: C150132.00

Dominion Possum Point Pond D Closure
Section 1
Undrained
Static Analysis
Initial GWT

By: KLS 11/30/15
Ck: MEZ 12/2/15

Soil Parameters:
Name: Embankment Soil Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 775 psf Phi: 18 ° Piezometric Line: 1
Name: Clay Foundation Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 750 psf Phi: 15 ° Piezometric Line: 1
Name: Ash Model: Mohr-Coulomb Unit Weight: 90 pcf Cohesion: 350 psf Phi: 18 ° Piezometric Line: 1
Name: Drainage Blanket Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 0 psf Phi: 37 ° Piezometric Line: 1

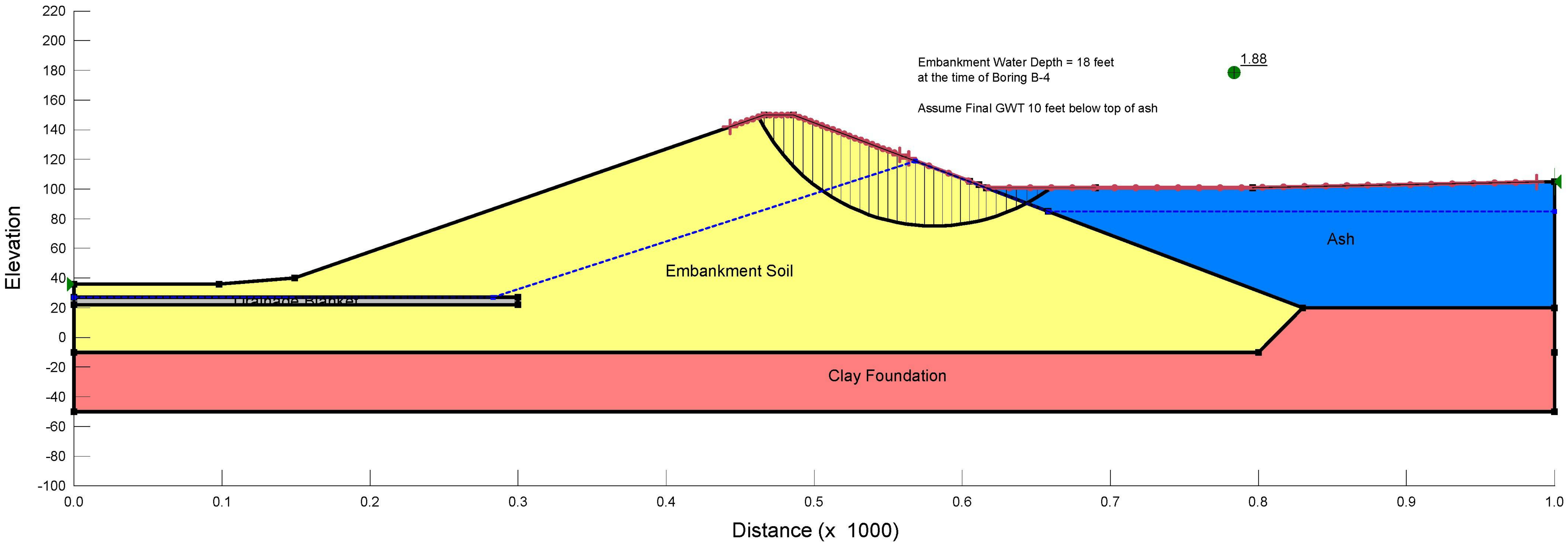


GAI Project: C150132.00

Dominion Possum Point Pond D Closure
Section 1
Undrained
Static Analysis
Rapid Drawdown

By: KLS 11/30/15
Ck: MEZ 12/2/15

Soil Parameters:
Name: Embankment Soil Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 775 psf Phi: 18 ° Piezometric Line: 1
Name: Clay Foundation Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 750 psf Phi: 15 ° Piezometric Line: 1
Name: Ash Model: Mohr-Coulomb Unit Weight: 90 pcf Cohesion: 350 psf Phi: 18 ° Piezometric Line: 1
Name: Drainage Blanket Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 0 psf Phi: 37 ° Piezometric Line: 1

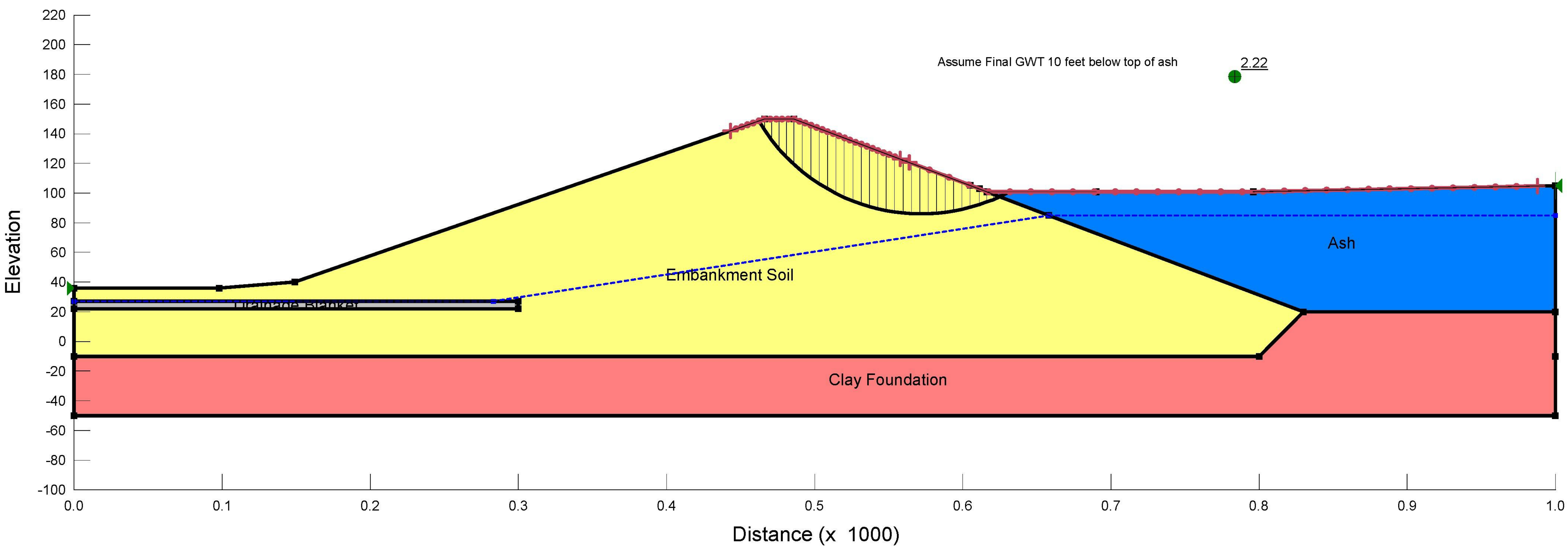


GAI Project: C150132.00

Dominion Possum Point Pond D Closure
Section 1
Undrained
Static Analysis
Final GWT

By: KLS 11/30/15
Ck: MEZ 12/2/15

Soil Parameters:
Name: Embankment Soil Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 775 psf Phi: 18 ° Piezometric Line: 1
Name: Clay Foundation Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 750 psf Phi: 15 ° Piezometric Line: 1
Name: Ash Model: Mohr-Coulomb Unit Weight: 90 pcf Cohesion: 350 psf Phi: 18 ° Piezometric Line: 1
Name: Drainage Blanket Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 0 psf Phi: 37 ° Piezometric Line: 1



ATTACHMENT 4

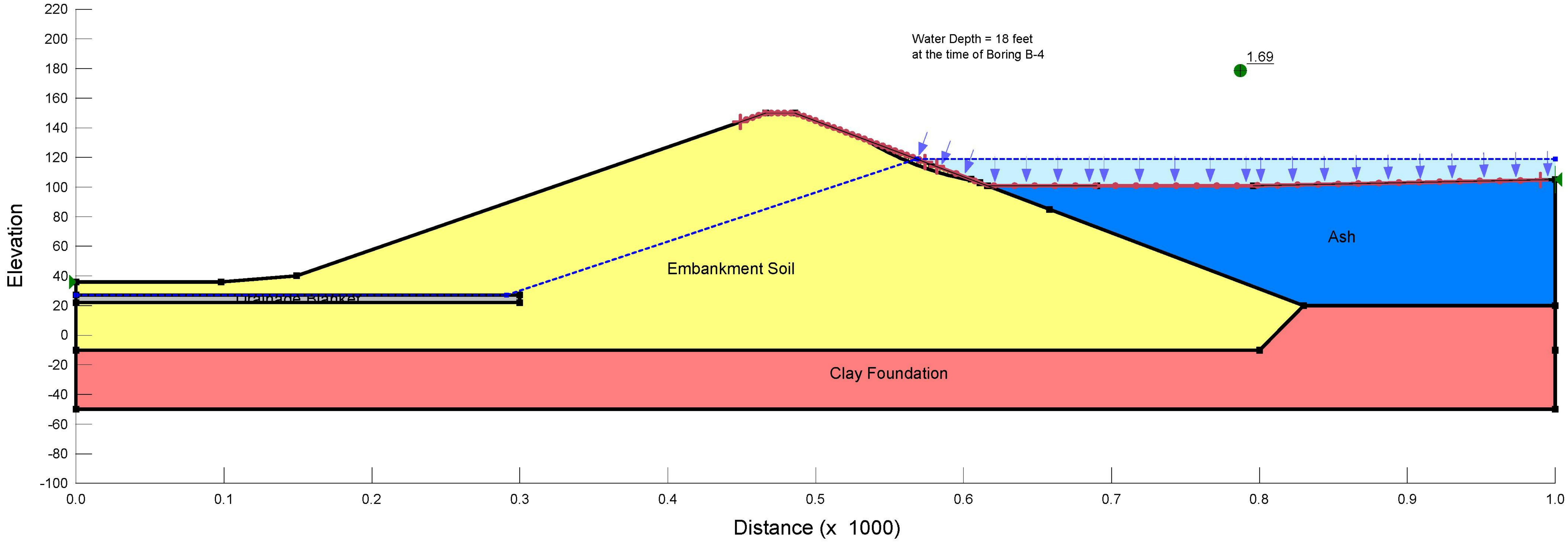
DRAINED SLOPE STABILITY ANALYSIS RESULTS

GAI Project: C150132.00

Dominion Possum Point Pond D Closure
Section 1
Drained
Static Analysis
Initial GWT

By: KLS 12/1/15
Ck: MEZ 12/2/15

Soil Parameters:
Name: Embankment Soil Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 0 psf Phi: 33 ° Piezometric Line: 1
Name: Clay Foundation Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 200 psf Phi: 25 ° Piezometric Line: 1
Name: Ash Model: Mohr-Coulomb Unit Weight: 90 pcf Cohesion: 0 psf Phi: 36 ° Piezometric Line: 1
Name: Drainage Blanket Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 0 psf Phi: 37 ° Piezometric Line: 1

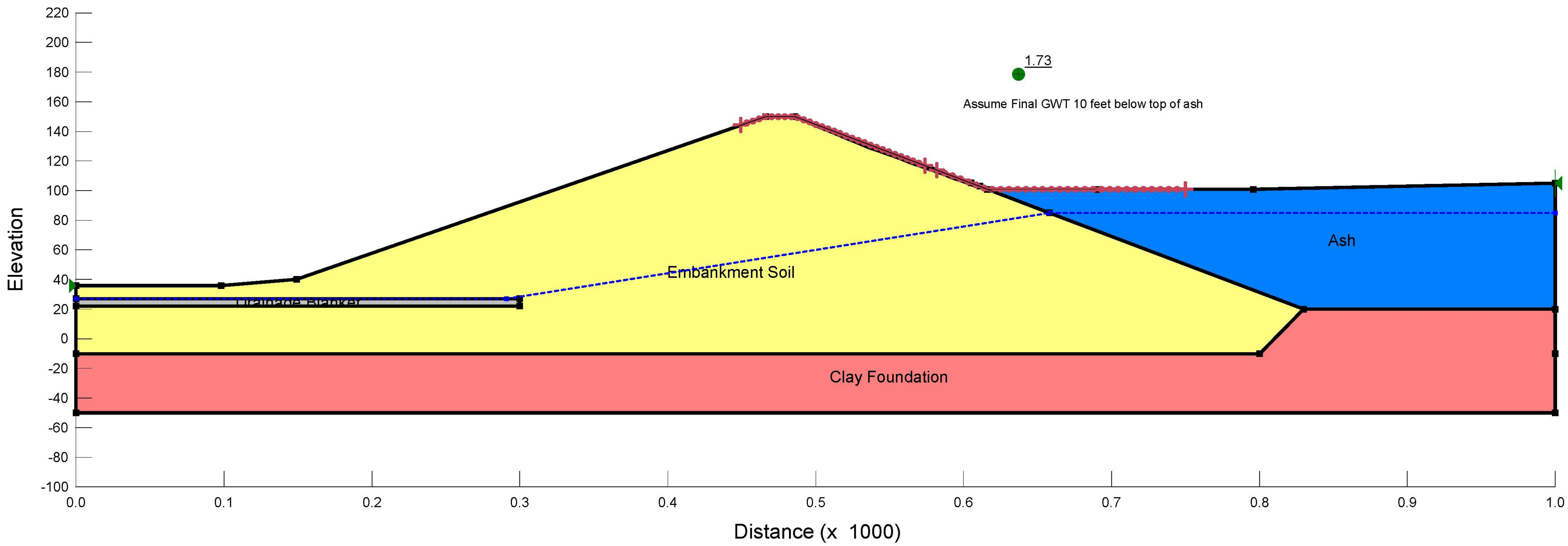


GAI Project: C150132.00

Dominion Possum Point Pond D Closure
Section 1
Drained
Static Analysis
Final GWT

By: KLS 12/1/15
Ck: MEZ 12/2/15

Soil Parameters:
Name: Embankment Soil Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 0 psf Phi: 33 ° Piezometric Line: 1
Name: Clay Foundation Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 200 psf Phi: 25 ° Piezometric Line: 1
Name: Ash Model: Mohr-Coulomb Unit Weight: 90 pcf Cohesion: 0 psf Phi: 36 ° Piezometric Line: 1
Name: Drainage Blanket Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 0 psf Phi: 37 ° Piezometric Line: 1



DEWATERING EVALUATION

OBJECTIVE:

Evaluate CCR porosity (n) and Degree of Saturation (S) for use in dewatering and pumping volumes estimates for Pond D at the Dominion Possum Point Power Station located in Prince William County, Virginia.

METHODOLOGY:

Porosity (n) and Degree of Saturation (S) are calculated from laboratory testing data of undisturbed samples obtained from Ponds A, B, C and D. Laboratory testing data is summarized below and in References 1 and 2, and n and S are calculated based on soil mechanics theory presented in Reference 3 also as described below.

REFERENCES:

1. GAI Report, "Geotechnical Summary Report," Dominion Generation, Possum Point Power Station, Coal Combustion Residual Surface Impoundment Closures Project, Prince William County, Virginia, October 2015.

2. GAI Calculation, "Dominion Possum Point Power Station – Pond D Closure Settlement Analysis," August 2015

3. Das, Braja M., "Principles of Geotechnical Engineering," PWS Publishers, 1985.

BACKGROUND:

Dominion is proposing the closure of Pond D located at the Possum Point Power Station in Prince William County, Virginia. Pond D is located just north of the power station and will include an approximate 70-acre geosynthetic cap area. The proposed closure of Pond D will utilize ash from Ponds A, B, C and E and will modify the existing grades of Pond D to facilitate surface water runoff and reduce infiltration. Also, a dewatering plan will be implemented within Pond D to extract water from the coal combustion residuals (CCR) prior to placement of ash/fill.

To estimate dewatering pumping rates and volume of water that could be extracted from ash materials in Pond D, an estimate of the water to be extracted is being performed. The water-extraction evaluation requires input of the CCR porosity, initial Degree of Saturation, and a realistic assumption for the potential final Degree of Saturation (post-dewatering).

ANALYSIS:

Laboratory testing data from undisturbed samples of Possum Point CCR is summarized below, which was obtained from References 1 and 2. Of particular interest is natural water content (w%), specific gravity (Gs) and void ratio (eo). The average values for Pond D samples, Ponds A, B and C samples and all samples combined are derived from the data.

The dewatering evaluation estimates the volume of water to be extracted from the upper 10 feet of the ash ponds and is based on porosity (n), and the initial (in-situ) and final (assumed) degree of saturation (S and Sf, respectively). Reference 3 provides the theory and relationships between soil w%, Gs and eo for determining n and S. The final Degree of Saturation (Sf) is based on an assumed, realistic final range of moisture content, and the post-dewatering void ratio and specific gravity are conservatively assumed to equal the in-situ values. This assumption will generate a lower Sf and thus a larger volume of water to be extracted.

SUBJECT: DOMINION POSSUM POINT POWER STATION – POND D CLOSURE
POROSITY (n) and DEGREE OF SATURATION (S) for DEWATERING EVALUATION

BY BEG DATE 12/4/15 PROJ. NO. C150132.00

CHKD. BY CAG DATE 12/4/15 SHEET NO. 2 OF 4

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From Reference 3, the relationship between porosity (n) and void ratio (e) is defined in Eq. 2.7 as:

$$n = e/(1+e)$$

and the Degree of Saturation (S) is defined in Eq. 2.17 in terms of moisture content (w), specific gravity (Gs) and void ratio (e) as:

$$Se = wGs, \text{ or}$$

$$S = wGs/e$$

Summary of Pond D Laboratory Testing Results (Reference 2)

Boring I.D.	Sample I.D.	Depth (ft)	SOIL ENGINEERING PROPERTIES											
			Specific Gravity	In-situ Parameters			Consolidated Unrained Triaxial				One-Dimensional Consolidation			
				w_{nat} (%)	Dry Unit Weight, γ_d (pcf)	Moist Unit Weight, γ_m (pcf)	ϕ' (deg)	c' (psi)	ϕ (deg)	c (psi)	e_0	C_c	C_r	OCR
ASH D-1	ST-7	12.0 - 14.0	2.04	98.3	38.1	75.5	36.6	0.5	17.9	3.7	1.646	0.474	0.027	5.781
ASH D-2	ST-14	27.4 - 27.9	2.12	82.1	49.7	90.4	38.6	0.1	22.4	2.4	1.902	0.334	0.055	3.042
ASH D-4	U-8	14.0 - 16.0	2.19	36.5	62.6	85.5	43.3	0.0	26.5	4.1	1.472	0.419	0.013	6.074
ASH D-5	U-5	22.0 - 24.0	2.05	103.3	39.5	80.2	34.9	2.2	16.3	8.8	1.752	0.384	0.048	4.155
ASH D-5	U-15	42.0 - 44.0	2.08	75.7	48.1	84.4	35.7	1.0	16.5	4.4	1.386	0.305	0.072	2.326
ASH D-6	U-3	13.0 - 15.0	2.06	82.4	42.8	78.1	33.8	2.5	15.2	11.2	0.926	0.103	0.007	6.825

Pond D Average 2.09 79.7 1.51

Summary of Ponds A, B and C Laboratory Testing Results (Reference 1)

Boring ID	Sample ID	Depth (ft)	Gs	w%	γd (pcf)	γt (pcf)	ϕ' (deg)	c' (psi)	ϕ (deg)	c (psi)	eo	Cc	Cr	OCR
Ash A-2	ST-3	10.0 -12.0	2.23	44.9	77.9	112.9	32.3	1.13	21.0	3.32	1.49	0.247	0.012	8.715
Ash B-2	ST-2	2.0 – 4.0	2.24	65.0	58.8	97.0	37.1	2.53	31.4	4.68	1.79	0.370	0.029	16.475
Ash C-2	ST-5	8.0 – 10.0	2.16	55.8	59.3	92.4	37.3	0.56	31.8	1.93	1.14	.0200	0.012	9.070
Ash C-3	ST-3	4.0 – 6.0	2.08	45.2	44.9	65.2	38.2	0.63	21.7	4.77	1.95	0.687	.010	9.962

Pond A, B, C Average 2.18 52.7 1.59

Pond A, B, C and D Average 2.13 68.9 1.55

(All Values)

Pond D – In-situ (initial) porosity (n) and Degree of Saturation (S) conditions:

$$n = 1.51/(1+1.51) = 0.60$$

$$S = [(79.7/100)*2.09]/1.51 = 1.1$$

Ponds A, B, C and D – In-situ (initial) porosity (n) and Degree of Saturation (S) conditions:

$$n = 1.55/(1+1.55) = 0.61$$

$$S = [(68.9/100)*2.13]/1.55 = 0.95$$

Use, n = 0.60 and S = 1.1 for water-extraction evaluation of Pond D in-situ (initial) conditions.

Pond D – Final (post-dewatering) Degree of Saturation (S_f) conditions:

Based on the Ponds A, B and C natural water contents, it is realistic to assume the final Pond D water content (post-dewatering) would be similar or slightly lower, i.e., $w \leq 0.52$.

Therefore, use a range of post-dewatering water content from w = 0.40 to 0.50.

Although there could be a slight reduction in void ratio during dewatering, assuming no change in post-dewatered void ratio is reasonable and conservative, i.e., e = 1.51, which will generate a larger volume of water extracted.

Also, no change in the material specific gravity is anticipated post-dewatering, therefore, the in-situ (average) Gs = 2.09 shown above is assumed.

Thus,

$$S_f \text{ min} = [(40.0/100)*2.09]/1.51 = 0.55$$

and,

$$S_f \text{ max} = [(50.0/100)*2.09]/1.51 = 0.69$$

Use, S_f = 0.55 minimum and S_f = 0.69 maximum for water-extraction evaluation of Pond D (final) Degree of Saturation conditions.

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CONCLUSIONS and RECOMMENDATIONS:

Based on site-specific, undisturbed samples of CCR materials from Ponds A, B, C and D, and corresponding laboratory testing results/data, porosity (n), and initial Degree of Saturation (S) and final Degree of Saturation (S_f) were calculated. The following values are recommended for dewatering evaluation:

- Use, n = 0.60 and S = 1.1 for water-extraction evaluation of Pond D in-situ (initial) conditions.
- Use, S_f = 0.55 minimum and S_f = 0.69 maximum for water-extraction evaluation of Pond D (final) Degree of Saturation conditions.

Applying the recommended porosity and Degree of Saturation, the range of water extraction volumes estimated for Pond D is approximately 50 million gallons to 70 million gallons.

Pond D Estimated Dewatering Volume

In-situ Ash Water				
Porosity	Initial Degree of Saturation	Final Degree of Saturation	Estimated Ash Volume* (CY)	In-Situ Volume to be Dewatered (million gallons)
0.6	1.1	0.55	1,032,500	68.81

Pond D Estimated Dewatering Volume

In-situ Ash Water				
Porosity	Initial Degree of Saturation	Final Degree of Saturation	Estimated Ash Volume* (CY)	In-Situ Volume to be Dewatered (million gallons)
0.6	1.1	0.69	1,032,500	51.30

*Note: 1,032,500 CY of ash volume assumes 64 acres of pond area dewatering to a depth of 10 feet.